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ABSTRACT

This presentation provides an in-process review of researching efforts at the U.S. Army Research Institute and the Institute for Defense Analysis to update their earlier studies of Computer Based Instruction (CBI) cost-effectiveness. In the presentation five topics are addressed: (1) the differences between education and training, and why they matter; (2) findings of earlier studies on the cost-effectiveness of CBI in military training; (3) some methodological issues uncovered by these earlier studies; (4) some methodological improvements applied to update these earlier studies; and (5) some preliminary results. Sixteen replicas of the slides used in the presentation are appended. (Author/JAZ)

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Cost-Effectiveness of CBI in Defense Training

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Cost Effectiveness of CBI in Defense Training

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SUMMARY

This presentation provides an in-process review of our efforts to update earlier studies of CBI cost-effectiveness. In the presentation we address five topics; (1) the differences between education and training, and why they matter; (2) findings of earlier studies on the cost-effectiveness of CBI in military training; (3) some methodological issues uncovered by these earlier studies; (4) some methodological improvements we are attempting in our efforts to update these earlier studies; (5) some preliminary results.

Slide 1. There are differences, primarily in emphasis, between the world of education with which most AERA members are familiar and the world of training which is the concern of the Department of Defense (DOD) and substantial portions of industry. Most important among these differences are: (1) the objectives of training are driven by specific jobs, and (2) education can be viewed as a positive end in its own right, training is a means to an end. It should be noted that training and education are distinguished by what they emphasize, most training includes components of education and vice versa. Also training and education are complementary, education prepares people for training and training motivates education.

These differences influence the methodology of cost-effectiveness studies. In training we are usually trying to achieve some threshold of effectiveness, so our studies hold effectiveness constant and look for cost reductions in obtaining it. We want to know how much it costs to

obtain a unit of effectiveness. In education we are usually trying to maximize effectiveness, so our studies usually hold costs constant and look for ways to maximize effectiveness given these costs. We want to know how much effectiveness we obtain from a unit of cost.

Slide 2. Training in the DoD is an immense activity. This slide shows FY1986 expenditures in excess of $19B, but this figure is only for residential training, mostly of individuals, conducted in formal courses. Excluded are major elements such as on the job training, field exercises, factory training to support new military systems, and mission specific training. The impact of cost-effective approaches such as those promised by CBI is proportionately large and of considerable interest to the military.

Slide 3. Our work is focused on four types of training. They are: (1) pilot training; (2) maintenance training; (3) operations training; and (4) CBI. As you will note, CBI is an approach rather than an applications area, and it cuts across the first three areas. Training approaches in the three application areas almost always involve simulation (often based on CBI). This emphasis on simulation also shapes the methodology we are using to study the cost-effectiveness of CBI. Studies that examine the effectiveness of training simulation are usually covered with the amount of post-simulation time students need to reach performance criterion with actual equipment.

Consequently, they are frequently concerned with measures of transfer and savings in student time. As you will see, these concerns influence our studies of CBI.

Slide 4. In 1979 Orlansky and String published a major review of the cost-effectiveness of CBI in military training. A concern of this review was the amount of student time saved by CAI and CMI. In the studies reviewed, students were randomly assigned either to a CBI group or a control group. Student time to complete the training was then recorded for both groups. Of the 48 studies shown in the slide, four found negative or zero time savings; 44 found positive time savings. Student time saved ranged from -31 to 89 percent, with a median savings of 30%. Since these studies showed reductions in student time, it is then natural to ask if there were proportionate reductions in student achievement.

Slide 5. The same 48 studies are shown in this slide. There is only one case in which the CBI group produced inferior performance. Generally, then, the CBI groups in these studies produced equivalent or better achievement in about a third less time than conventional groups. If student time is a sufficient measure of cost -- and military students are paid while they are trained -- we could conclude from these studies that CBI is a cost-effective alternative to conventional instruction. However, three issues, among others, seem worth mentioning at this point. First, student time may not suffice as a measure of cost. Second, end of course achievement may not suffice as a measure of achievement. Third, many of these studies do not provide a clear comparison of CBI with conventional instruction.

Slide 6. This slide outlines some cost elements that can be considered in training. A number of cost element structures have been produced for training and education. However, the four main headings here (Research and Development, Initial Investment, Operating and Support, Salvage and

Recovery) are fairly standard. Those of you familiar with the ephemeral nature of budgets for instructional research, development, and evaluation will recognize that proper costing of an instructional program may well consume all available resources for evaluation. Student pay may be a significant element of training costs, but it may not suffice as a substitute for all the elements presented here.

Slide 7. This slide outlines some effectiveness measures that can be considered in training. In instructional evaluation we are frequently satisfied with a single end of course measure of effectiveness. This measure may frequently suffice for education, but in training we are usually looking for several outcomes -- each of which needs to be measured and weighted in an adequate evaluation study. End of course accuracy of performance may not suffice as a measure of training effectiveness.

Slide 8. You might wonder what coverage of cost and effectiveness elements we obtain in 'real world' studies. The numbers presented in this slide come from a review of 22 very recent empirical studies of military training performed in 5 NATO countries -- including the United States. As you can see, coverage of cost and effectiveness elements is spotty.

Slide 9. This slide outlines the development and evaluation cycle for most of the studies reviewed by Orlansky and String -- and others as well. As you can see the evaluation compares conventional instruction with at least two other approaches: (1) instructional systems design "clean up" of the original course; (2) individualization of the resulting course; and (3) CBI presentation of the resulting cleaned up and individualized course. In 12 of the studies reviewed by Orlansky and String, there was a phase of development between conventional and computer-based instruction,

where the courses were given temporarily by self-paced means (i.e. individualized for pace) without computer support. In these instances, it was possible to compare student achievement and time needed to complete a course under three conditions: conventional, individualized for pace, and computer-based.

Slide 10. In these instances, cleaned-up, individualized instruction without computer support saved 50% or more of the student time required to reach criterion. The addition of CMI saved nothing; the addition of CAI saved an additional 5%. Did the CAI approach matter? Two of the 5 CAI studies reduced student time by about 20% compared to non-CAI self-pacing. One of the CAI studies increased student time by about 10% more than non-CAI self pacing. Would individualization for content or learning style provide a better case for CBI? Were the measures of training outcome commensurate with the training objectives in these cases? This analysis is not conclusive, but it does illuminate some of the methodological issues we face even in the well explored territory of effectiveness.

On this basis, we conclude that CBI is an effective approach for military training, but this is certainly an arguable conclusion. The issue of cost-effectiveness remains unsettled -- hence our interest in updating the earlier studies and adding whatever new information we can.

Slide 11. Our current approach to CBI cost-effectiveness keys on ratios. Cost-effectiveness is treated as a ratio of costs to effectiveness. Costs are measured as the ratio of costs for one training approach to another. Finally, effectiveness is measured as the ratio of effectiveness for one training approach to another. This slide shows the derivation of the Training Cost Ratio (TRC). Once we have satisfactory cost measures, which

are not easy to come by, the TCR is straight-forward to obtain and interpret. If the TCR = 1.00, both approaches cost the same. Because we put CBI cost in the numerator, the smaller the TCR, the less costly the relative cost of CBI. There is no standardized, minimal, agreed-upon set of costs to be collected for TCRs, and comparability among TCRs for different studies is limited.

Slide 12. The measure of effectiveness is also difficult. One common measure from aircraft simulation studies is the Transfer Effectiveness Ratio (TER). The TER provides a quantative measure of the value added to a training program by the use of simulation. It is expressed as the ratio of training time saved by use of simulation to the amount of time allocated to simulation. Positive TERs indicate positive transfer of training, i.e. a savings in actual equipment time attributable to time spent in simulator training. The larger the positive value of a TER, the greater the training value added by simulation.

Slide 13. Another common measure of effectiveness is Effect Size (ES) which is used in many meta-analytic studies of instructional approaches. The experimental group is usually the CBI group in this ratio. Therefore, the larger the ES, the greater the relative effectiveness of the CBI approach.

Slide 14. In much of our recent work, we have been using a simple Performance Effectiveness Ratio (PER). Usually we put the effectiveness for the CBI group in the numerator so that the larger the value obtained, the greater the relative effectiveness of the CBI approach.

Slide 15. What we are aiming for is a reasonably robust ratio of cost to effectiveness -- a cost-effectiveness ratio (CER). This tells us how much it costs to achieve a unit of effectiveness. If we were concerned with

education, we might prefer an effectiveness to cost ratio, but the basic idea would be the same. In our case, the lower the CER value, the greater the cost-effectiveness of the approach being considered.

Here are some specifications for CERs:

(1) Since each CER represents the cost and effectiveness of two different approaches to training, we would like the value of the CER by itself to indicate which of the approaches is the most cost-effective alternative;

(2) We would like to be able to compare different CERs with each other so that they map into an ordinal, or better yet, interval scale;

(3) We would like the CERs to be defined so that lesser effectiveness is compensated for by lower cost and conversely;

(4) We would like the CERs to be commensurable so we can estimate the cost-effectiveness of different approaches by making comparisons across a number of CERs.

The closest we came to these specifications was with a CER defined as the ratio of TCR to PER. The threshold value in this case is 1.00, and the lower bound is zero. Commensurability depends on the values going into the TCR and PER. TERs are not needed, but the data used to calculate them can be used to calculate PERs.

Slide 16. Progress is occurring. Evaluators are more frequently including costs in their assessments of training alternatives and cost analysts are more frequently including measures of effectiveness. In updating the cost-effectiveness surveys, we are now extracting TERs, PERs, TCRs, and CERs rather than just looking at student time savings and effectiveness differences. This slide shows data extracted from 18

studies of CBI effectiveness. The data illustrate the kind of numbers and information we are looking for. Notably, we had to cull through more than 100 studies to provide these data. Although matters are improving for cost-effectiveness evaluations, the necessary data are still scarce.

The ECRs reported here are reciprocals of the CERs. We compared computer assisted instruction (CAI) with computer managed instruction (CMI) and Maintenance Training (MT) with Operations Training (OT). We also present totals for all 18 studies. On the basis of these limited data, we would conclude that CAI is slightly more cost-effective than CMI, that CBI is about equally effective for maintenance and operator training, and that, overall, CBI is a cost-effective alternative for defense training, saving about 28 cents per unit of achievement over conventional training approaches -- or providing about .39 units of achievement more per training dollar spent.

It is important to note that measures of effectiveness differed across these studies and that costs were not drawn from a common cost element structure. As indicators, these data are valuable. As conclusive evidence, they need improvement.

SLIDE 1

TRAINING ⟷ EDUCATION

- Specific Skills
- Facts and Procedures
- Job-Based Objectives
- Fixed Objectives
  Minimized Costs

- General Capabilities
- Concepts and Rules
- Career-Based Objectives
- Fixed Costs,
  Maximized Performance

SLIDE 2

INDIVIDUAL TRAINING AT MILITARY SCHOOLS FY 1986

Type of Training	Students (000)		Cost (Billions)
	Number (Input)	Man-Years	
Recruit	370	58	$ 1.4
Army One-Station Unit*	87	21	0.4
Officer Acquisition	15	19	0.5
Specialized Skill	1370	147	4.9
Flight	19	7	2.5
Professional Development	58	11	0.8
Medical			0.7
(Support Costs)			8.0
Total	1919	263	$19.1

*Recruit and Initial Skill Training

Source: Military Manpower Training Report for FY 1986

SLIDE 3

INSTRUCTION TYPES

* PILOT TRAINING
* MAINTENANCE TRAINING
* OPERATIONS TRAINING
* COMPUTER BASED INSTRUCTION (CBI)

SLIDE 4

AMOUNT OF STUDENT TIME SAVED IN COURSES GIVEN BY CAI AND CMI, COMPARED TO CONVENTIONAL INSTRUCTION, IN MILITARY TRAINING

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT TIME SAVINGS (compared to conventional instruction)	TYPE OF TRAINING	REFERENCES
CAI	IBM 1500	A	SIGNAL C&S		ELECTRONICS	IBM (1968), Longo (1969, 1972) Glaser and Longo (1971 a&b)
		N	SAN DIEGO		ELECTRICITY	Ford & Stough (1970), Hurlock & Lahey (1971, 1972), Ford, Stough *et al* (1972)
	PLATO IV	A	ABERDEEN		MACHINIST	U.S. Army Ordnance Center and School (1975)
		N	SAN DIEGO		ELECTRONICS	Stern (1975), Lahey, Crawford *et al* (1976), Stough and Cosby (unpubl.)
		N	SAN DIEGO		RECIPE CONVERSION	Fredericks and Hoover-Rice (1977)
		N	NORTH ISLAND		A/C PANEL OPERATOR	Crawford, Hurlock *et al* (1976)
		AF	SHEPPARD		MEDICAL ASSISTANT	Steinbrecher, Holguin *et al* (1977), Holguin and Duncan (1977)
		AF	CHANUTE		VEHICLE REPAIR	Bellman, DeLeo *et al* (1977)
	LTS-3	AF	KEESLER		ELECTRONICS	Hanks, Greenberg *et al* (1972), Keesler AFB (1972, 1973)
		AF	KEESLER		WEATHER	Brown, Johnson *et al* (1972)
	TICCIT	N	NORTH ISLAND		TACTICAL CO-ORD. (S-3A)	Walker (1978)
	IBMDH	N	BAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Redshaw and Brennan (1975)
	PLATO IV	N	BAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Redshaw and Brennan (1975)
CMI	NAVY CMI	N	MEMPHIS		AVIATION FAMILIARIZATION	Carson, Graham *et al* (1975)
		N	MEMPHIS		AV. MECH. FUNDAMENTALS	Carson, Graham *et al* (1975)
	AIS	AF	LOWRY		INVENTORY MGMT.	Briefing (1978)
		AF	LOWRY		MATERIEL FACILITIES	Briefing (1978)
		AF	LOWRY		PREC. MEASURING EQPT.	Briefing (1978)
		AF	LOWRY		WEAPONS MECHANIC	Briefing (1978)

-40 -20 0 20 40 60 80 100 percent

SLIDE 5

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT ACHIEVEMENT AT SCHOOL (compared to conventional instruction)			TYPE OF TRAINING
				INFERIOR	SAME	SUPERIOR	
CAI	IBM 1500	A	SIGNAL C&S		• • • •	• •	ELECTRONICS
		N	SAN DIEGO			• • • • •	ELECTRICITY
	PLATO IV	A	ABERDEEN		• • •		MACHINIST
		N	SAN DIEGO		• •	• • • •	ELECTRONICS
		N	SAN DIEGO		• •		RECIPE CONVERSION
		N	NORTH ISLAND			•	A/C PANEL OPERATOR
		AF	SHEPPARD		• •	• •	MEDICAL ASSISTANT
		AF	CHANUTE		• • • •		VEHICLE REPAIR
	LTS-3	AF	KEESLER		• •	•	ELECTRONICS
		AF	KEESLER		•		WEATHER
	TICCIT	N	NORTH ISLAND		•		TACTICAL CO-ORD. (S-3A)
	IDBOM	N	DAM NECK	•	•		FIRE CONTROL TECHNICIAN
	PLATO IV	N	DAM NECK		• •		FIRE CONTROL TECHNICIAN
				TOTAL 1	24	15	
CMI	NAVY CMI	N	MEMPHIS		• •		AVIATION FAMILIARIZATION
		N	MEMPHIS		• •		AV. MECH. FUNDAMENTALS
	AIS	AF	LOWRY		•		INVENTORY MGMT.
		AF	LOWRY		•		MATERIEL FACILITIES
		AF	LOWRY		•		PREC. MEASURING EQPT.
		AF	LOWRY		•		WEAPONS MECHANIC
				TOTAL 0	8	0	

SLIDE 6

COST CATEGORIES/ELEMENTS
A. RESEARCH AND DEVELOPMENT
1. Design
2. Component Development
3. Producibility Engineering and Planning
4. Tooling
5. Prototype Manufacturing
6. Data
a. Managerial
b. Technical
7. P/C/D Test and Evaluation
8. System/Project Management
9. Facilities
10. Other
B. INITIAL INVESTMENT
1. Production
a. Nonrecurring
(1) Production Planning
(2) Production Tooling and Equipment
(3) Industrial Facilities
(4) Others
b. Recurring
(1) Manufacturing
(2) Sustaining Engineering
(3) Sustaining Tooling
(4) Quality Assurance
(5) Other
c. Initial Spares and Repair Parts
2. Engineering changes
3. Purchased P/C/D-Peculiar Equipment
4. Common Equipment
5. Data
a. Managerial
b. Technical
c. Instruction Materials
6. P/C/D Test and Evaluation
7. System/Project Management
8. Rents
9. Operational/Site Activation

COST CATEGORIES/ELEMENTS
(2) Other Government Personnel Costs
(3) Other
c. Airfield and Carrier Operations Costs
(1) Pay and Allowances
(2) Other Government Personnel Costs
(3) Other
d. Student Costs
(1) Pay and Allowances
(2) Other Student Costs
e. Other Direct Costs
2. Indirect Costs
a. Base Operations
(1) Pay and Allowances
(2) Other Government Personnel Costs
(3) Other
b. Inventory and Supply Management
(1) Pay and Allowances
(2) Other Government Personnel Costs
(3) Other
c. Military Family Housing Support
(1) Pay and Allowances
(2) Other Government Personnel Costs
(3) Other
d. Command Support Costs
(1) Pay and Allowances
(2) Other Government Personnel Costs
(3) Other
e. Other Indirect Costs

COST CATEGORIES/ELEMENTS
10. Initial Training
a. Instructors
b. Maintenance Personnel
11. Transportation
a. First Destination
b. Second Destination
12. Other
C. OPERATING AND SUPPORT
1. Direct Costs
a. Instructional Costs
(1) Pay and Allowances
(a) Instructors
(b) Supervisors, Administrative and Support Personnel
(c) Maintenance Personnel
(2) Other Government Personnel Costs
(3) Consumption
(a) POL
(b) Training Munitions
(c) Utilities
1 Electric Power
2 Other
(d) Instructional Materials
(e) Other
(4) Replenishments Spares
(5) Modification Material
(6) Depot Maintenance
(a) Labor and Materials
(b) Second-Destination transportation
(c) Other
(7) Other Purchased Services
(8) Other
b. Training Activity Costs
(1) Pay and Allowances

SLIDE 7

EFFECTIVENESS MEASURES

END OF COURSE

- SPEED OF PERFORMANCE
- ACCURACY OF PERFORMANCE

TRANSFER

ON THE JOB

STUDENT ATTRITION

INSTRUCTOR ATTITUDES

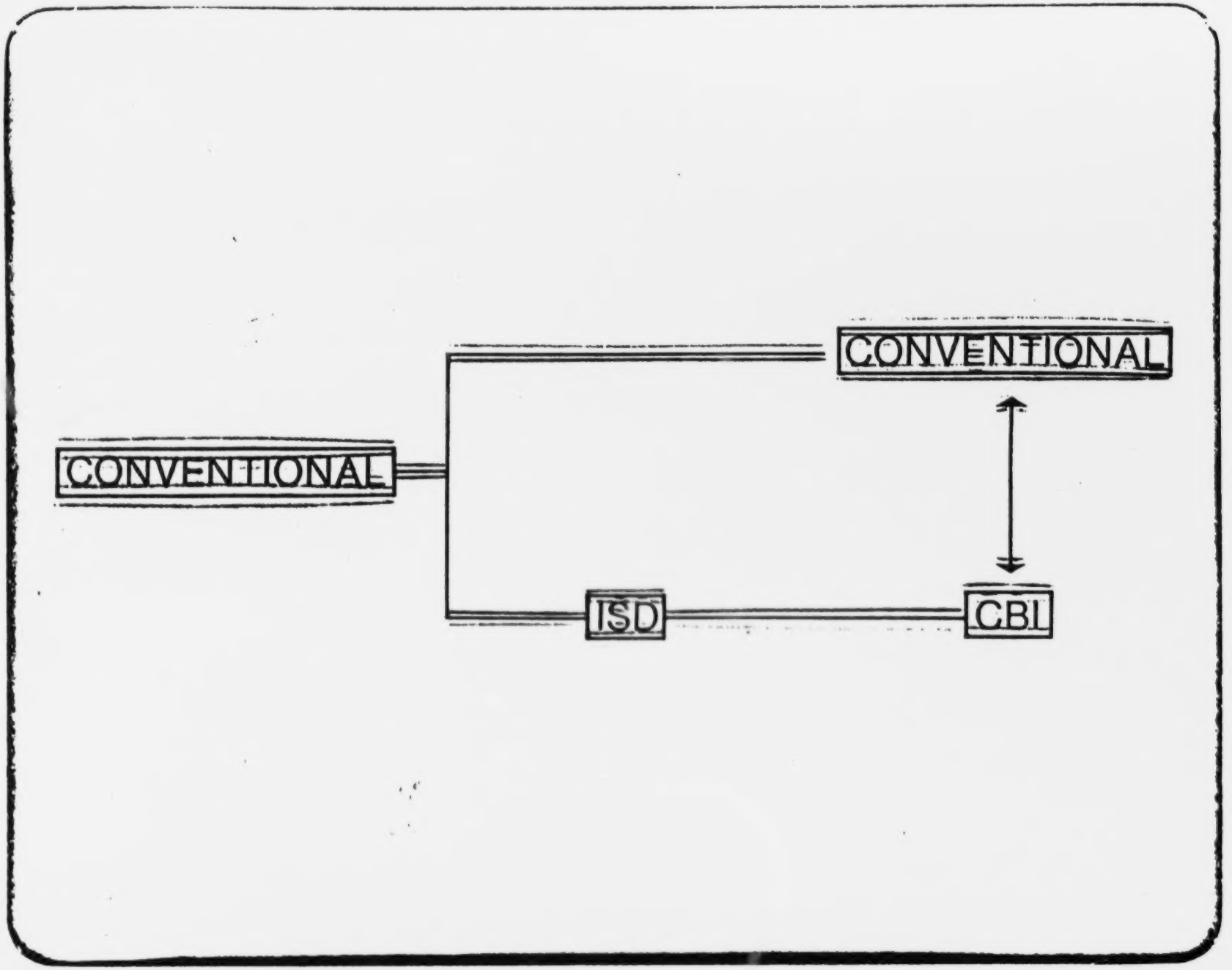
STUDENT ATTITUDES

INSIGHT

SLIDE 8

Types of Data	Number of Studies
Effectiveness Measures	
End of Course	22
Transfer	20
On the Job	0
Student Attrition	3
Instructor Attitudes	7
Student Attitudes	7
Cost Measures	
Research and Development	0
Initial Investment	
Program Development	0
Acquisition	2
Operating and Support	
Student Pay and Allowances	0
Instructor Pay and Allowances	0
Maintenance and Repair	0
Program Modification	0
Student Time Savings	8
Operating	5
Life-Cycle Costs (Includes all of the above)	2

SLIDE 9



SLIDE 10

NO. OF COURSES	AVERAGE AMOUNT OF STUDENT TIME SAVED		
	INDIVIDUALIZED INSTRUCTION	CAI	CMI
5	64%	69%	—
7	51%	—	51%

SLIDE 11

$$TCR = \frac{C_s}{C}$$

WHERE:

C_s = COST OF SIMULATOR BASED TRAINING

C = COST OF THE ACTUAL EQUIPMENT TRAINING

SLIDE 12

$$TER = \frac{A - A_S}{S}$$

WHERE:

A = REQUIRED TIME USING ACTUAL EQUIPMENT WITHOUT PRIOR USE OF SIMULATOR

A_S = REQUIRED TIME USING ACTUAL EQUIPMENT WITH PRIOR USE OF SIMULATOR

S = TIME SPENT TRAINING IN THE SIMULATOR

SLIDE 13

$$ES = \frac{A_E - A_C}{SD}$$

WHERE:

A_E = ACHIEVEMENT OF EXPERIMENTAL GROUP

A_C = ACHIEVEMENT OF CONTROL GROUP

SD = EITHER

(A) COMBINED STANDARD DEVIATION

OR

(B) CONTROL GROUP STANDARD DEVIATION

SLIDE 14

$$PER = \frac{A_E}{A_C}$$

WHERE:

A_E = ACHIEVEMENT OF EXPERIMENTAL GROUP

A_C = ACHIEVEMENT OF CONTROL GROUP

SLIDE 15

CER SPECIFICATIONS:

- THRESHOLD VALUE
- INTEGRAL SCALE
- COST/EFFECTIVENESS COMPENSATION
- COMMENSURABILITY

$$CER = \frac{TRC}{PER}$$

WHERE:

TRC = TRAINING COST RATIO

PER = PERFORMANCE RATIO

SLIDE 16

TYPE	N	PER	TCR	CER	ECR
CAI	11	1.04	.68	.67	1.49
CMI	7	1.26	.88	.76	1.32
MT	11	1.17	.77	.70	1.43
OT	7	1.05	.75	.73	1.37
TOTAL	18	1.15	.76	.72	1.39